Please enter

Application No. 10/038,120
Amendment "B" dated September 8, 2004
Reply to Office Action mailed June 16, 2004

AMENDMENTS TO THE CLAIMS

The listing of claims will replace all prior versions, and listings, of claims in the application:

Listing of Claims:

1. (Currently Amended) A bi-functional catalyst useful for oxidation and removal of nitrogen oxides (NOx) contained in fuel combustion gases, the catalyst comprising:

an adsorption function metal oxide component comprising at least one metal oxide selected from the group consisting of oxides of barium, cesium, lanthanum, strontium, and zirconium,

wherein said adsorption metal oxide component includes lanthanum,

said adsorption function metal oxide component providing adsorption function and adsorption sites for nitrogen oxides in fuel combustion gases; and

an oxidation function metal oxide component comprising at least one metal oxide selected from the group consisting of chromium, cobalt, copper, iron, manganese, and platinum,

wherein said oxidation metal oxide component includes at least one of copper or manganese promoted with platinum,

said oxidation function metal oxide component providing an oxidation function and oxidation sites for nitrogen oxides in fuel combustion gases,

said adsorption metal oxide component and said oxidation metal oxide component being combined together in close intimate contact so that said adsorption metal oxide component and said oxidation metal oxide component are chemically bonded closely together so as to form a metal oxide complex having a crystalline structure,

said adsorption sites and oxidation sites for nitrogen oxides within the bi-functional catalyst being adjacent to each other and arranged so as to promote adsorption and oxidation of nitrogen oxides when exposed to fuel combustion gases containing nitrogen oxides,

the molar ratio of metal within the adsorption function metal oxide component to metal within the oxidation function metal oxide component being in a ratio range of 0.1:1 to 5:1 in the bi-functional catalyst.

2. (Previously Presented) The bi-functional catalyst of claim 1, wherein said oxidation function metal oxide component includes copper, manganese, and platinum, and the molar ratio of metal within the adsorption function metal oxide component to metal within the oxidation function metal oxide component is in a range of about 0.2:1 to 2:1.

3. (Currently Amended) The bi-functional catalyst of claim 1, wherein said adsorption function metal oxide component includes ~~at least one of~~ barium (Ba) ~~or lanthanum (La)~~, and said metal oxide oxidation component includes copper (Cu) and manganese (Mn) promoted with platinum (Pt).

4. (Cancelled).

5. (Previously Presented) The bi-functional catalyst of claim 1, wherein said adsorption metal oxide component includes barium (Ba), and said oxidation metal oxide component includes copper (Cu), and optionally manganese (Mn), promoted with platinum (Pt).

6. (Previously Presented) The bi-functional catalyst of claim 1, wherein said bi-functional catalyst is provided on a porous support material having surface area of at least about 50 m^2/g.

7. (Currently Amended) A bi-functional catalyst useful for oxidation and removal of nitrogen oxides (NOx) contained in fuel combustion gases, the catalyst comprising:

an adsorption function metal oxide component comprising ~~at least one of barium or~~ lanthanum and providing adsorption function and adsorption sites for nitrogen oxides in fuel combustion gases; and

an oxidation function metal oxide component ~~selected from the group consisting of~~ comprising at least one of copper [[,]] or manganese ~~and~~ promoted with platinum and providing oxidation function and oxidation sites for nitrogen oxides in fuel combustion gases,

said adsorption metal oxide component and said oxidation metal oxide component being combined intimately together so that said adsorption metal oxide component and said oxidation metal oxide component are chemically bonded closely together so as to form a metal oxide complex having a crystalline structure,

said adsorption sites and oxidation sites for nitrogen oxides within the bi-functional catalyst being adjacent to each other and arranged so as to promote adsorption and oxidation of nitrogen oxides when exposed to fuel combustion gases containing nitrogen oxides,

the molar ratio of metal within the adsorption function metal oxide component to metal within the oxidation function metal oxide component being in a range of 0.2:1 to 2:1,

said metal oxide components being provided on a porous inert support material having surface area of 50-500 m^2/g.

8. (Previously Presented) A method for making a bi-functional catalyst suitable for catalytic oxidation of nitrogen oxides (NOx) contained in fuel combustion gases, comprising:

(a) providing an aqueous solution of adsorption function metal ions selected from the group consisting of barium, cesium, lanthanum, strontium and zirconium and combinations thereof for providing an adsorption function and adsorption sites in the bi-functional catalyst for adsorbing nitrogen oxide contained in combustion gases;

(b) providing an aqueous solution of oxidation function metal ions selected from the metals group consisting of chromium, cobalt, copper, iron, manganese and platinum for providing an oxidation function and oxidation sites for in the bi-functional catalyst oxidizing nitrogen oxides in combustion gases,

said adsorption function metal ions having a molar ratio to the oxidation function metal ions in the range of 0.1:1 to 5:1;

(c) mixing said adsorption and oxidation function metal ion solutions together and adding a binding agent acid having at least two functional groups selected for providing close intimate contact of said metal ions to form a precursor solution;

(d) drying said precursor solution and heating to a temperature of 500-800°C (930-1470°F) to form a metal oxide complex precursor material, then cooling the metal oxide complex precursor material; and

(e) forming a second solution of oxidation function metal ions and a platinum salt, and impregnating said precursor material with said second solution, then drying and calcining the impregnated precursor material at 500-800°C temperature and cooling to yield the bi-functional catalyst.

9. (Previously Presented) The method for making a bi-functional catalyst of claim 8, wherein the binding agent acid comprises carboxylic acid having a molar ratio of acid to total metals in a range of 0.5:1 to 2:1.

10. (Previously Presented) The method for making a bi-functional catalyst of claim 9, wherein the carboxylic binding acid comprises citric acid.

11. (Previously Presented) The method for making a bi-functional catalyst of claim 9, wherein the carboxylic binding acid comprises sodium citrate.

12. (Previously Presented) A method for making a bi-functional catalyst suitable for catalytic oxidation of nitrogen oxides (NOx) contained in fuel combustion gases, comprising:

(a) providing an aqueous solution of adsorption function metal ions selected from the group consisting of barium (Ba) and lanthanum (La) for providing an adsorption function and adsorption sites in the bi-functional catalyst for adsorbing nitrogen oxides contained in combustion gases;

(b) providing an aqueous solution of oxidation function metal ions selected from the metals group consisting of copper (Cu) and manganese (Mn) for providing an oxidation function and oxidation sites in the bi-functional catalyst for oxidizing nitrogen oxides contained in combustion gases,

said adsorption function metal ions having a molar ratio to the oxidation function metal ions in the range of 0.1:1 to 5:1;

(c) mixing said adsorption and oxidation function metal ion solutions together and adding a binding agent acid having at least two functional groups for providing close intimate contact of said metal ions to form a precursor solution;

(d) drying said precursor solution and heating to a temperature of 500-800°C (930-1470°F) to form a metal oxide complex precursor material, then cooling the metal oxide complex precursor material; and

(e) forming a second solution of oxidation function metal ions comprising manganese (Mn) ions and a platinum (Pt) salt, and impregnating said metal oxide complex precursor material with the second solution, then drying and calcining the impregnated precursor material at 500-800°C temperature and cooling to yield the bi-functional catalyst.

13. (Previously Presented) The method for making a bi-functional catalyst of claim 12, wherein said adsorption function metal ions comprise barium (Ba).

14. (Previously Presented) The method for making a bi-functional catalyst of claim 12, wherein said adsorption function metal ions comprise lanthanum (La).

15. (Previously Presented) The method for making a bi-functional catalyst of claim 12, wherein said adsorption function metal ions comprise barium (Ba) and said oxidative function metal ions comprise copper (Cu) and manganese (Mn) promoted with platinum (Pt).

16. (Original) The method for making a bi-functional catalyst of claim 8, including depositing the catalyst in powder form onto a porous support material.

17. (Previously Presented) A process for catalytic oxidation and removal of nitrogen oxides (NOx) contained in fuel combustion gases, the process comprising:

(a) providing a combustion gas stream containing nitrogen oxides (NOx) together with oxygen; and

(b) contacting said combustion gas stream with the bi-functional oxidation catalyst of claim 1 in order for said catalyst to adsorb and oxidize at least a portion of the nitrogen oxides (NOx) in said combustion gas stream at a temperature in a range of 170-550°F, a pressure in a range of 0.5-20 psig, and a space velocity in a range of 5,000-100,000 hr^{-1} to form higher oxides of nitrogen and thereby yield a treated combustion gas stream containing partially oxidized nitrogen oxides (NOx).

18. (Previously Presented) The catalytic oxidation process of claim 17, wherein said combustion gas stream contains up to 0.5 vol. % nitrogen oxides (NOx).

19. (Previously Presented) The catalytic oxidation process of claim 17, wherein said combustion gas stream in (b) has a temperature in a range of 200-500°F, a pressure in a range of 1-15 psig, and a space velocity in a range of 8,000-50,000 h^{-1}, and wherein the nitrogen oxides (NOx) in the treated combustion gas stream comprises at least about 50 vol % NO_2.

20. (Previously Presented) The catalytic oxidation process of claim 19, wherein the nitrogen oxides (NOx) in the treated combustion gas stream contains 60-98 vol % NO_2.

21. (Cancelled)

22. (Previously Presented) The catalytic oxidation process of claim 17, wherein said combustion gas stream contains up to 0.2 vol. % NO_x .

23. (Previously Presented) The catalytic oxidation process of claim 17, further comprising:

(c) contacting said treated gas stream containing partially oxidized nitrogen oxides (NOx) with a chemical oxidant having a molar ratio of said chemical oxidant to nitrogen oxides (NOx) in a range of 0.5:1 to 1.2:1 to further oxidize the partially oxidized nitrogen oxides (NOx) to higher oxides of nitrogen; and

(d) scrubbing the treated combustion gas stream containing the higher oxides of nitrogen with a scrubbing liquid to remove the higher oxides of nitrogen from the treated combustion gas and yield a further treated combustion gas stream containing less than about 15 ppm nitrogen oxides (NOx).

24. (Previously Presented) The catalytic oxidation process of claim 23, wherein (c) is performed at a temperature in a range of 100-250°F and a pressure in a range of 0.8-1.4 psig.

25. (Previously Presented) The catalytic oxidation process of claim 23, wherein said chemical oxidant comprises ozone (O_3), and wherein the molar ratio of the ozone (O_3) to the nitrogen oxides (NOx) in said treated combustion gas stream is 0.8:1 to 1.0:1.

26. (Previously Presented) The catalytic oxidation process of claim 23, wherein said scrubbing liquid comprises water.

27. (Previously Presented) The catalytic oxidation process of claim 23, wherein (b) is performed at a temperature in a range of 300-350°F.

28. (Previously Presented) The catalytic oxidation process of claim 23, wherein the further treated combustion gas stream formed in (d) contains less than about 10 ppm nitrogen oxides (NOx).

29. (Cancelled)

30. (Cancelled)

31. (Cancelled)

32. (Currently Amended) A bi-functional catalyst useful for oxidation and removal of nitrogen oxides (NOx) contained in fuel combustion gases, the catalyst comprising:

an adsorption function metal oxide component comprising <u>lanthanum oxide and optionally</u> at least one <u>other</u> metal oxide selected from the group consisting of oxides of barium, cesium, ~~lanthanum,~~ strontium, and zirconium and providing adsorption function and adsorption sites for nitrogen oxides in fuel combustion gases; and

an oxidation function metal oxide component comprising at least one <u>of copper or manganese promoted with platinum and optionally at least one other</u> metal oxide selected from the group consisting of chromium, cobalt, ~~copper,~~ iron, ~~manganese,~~ and platinum and providing an oxidation function and oxidation sites for nitrogen oxides in fuel combustion gases,

said adsorption metal oxide component and said oxidation metal oxide component being combined together in close intimate contact by means of an intermediate aqueous solution, comprising (i) at least type of adsorption function metal ions, (ii) at least one type of oxidation function metal ions, and (iii) a binding acid agent, that is heated and dried in order for said adsorption and oxidation metal oxide components to be chemically bonded closely together so as to form a metal oxide complex having a crystalline structure,

the molar ratio of the adsorption function metal ions to the oxidation function metal ions in the intermediate aqueous solution being in a range of 0.1:1 to 5:1.

33. (Cancelled)

34. (Cancelled)

35. (Previously Presented) A bi-functional catalyst useful for oxidation and removal of nitrogen oxides (NOx) contained in fuel combustion gases, the catalyst comprising:

an adsorption function metal oxide component comprising at least one metal oxide selected from the group consisting of oxides of barium, cesium, lanthanum, strontium, and zirconium; and

an oxidation function metal oxide component comprising at least one metal oxide selected from the group consisting of chromium, cobalt, copper, iron, manganese, and platinum,

said adsorption metal oxide component and said oxidation metal oxide component being combined together in close intimate contact so that said adsorption metal oxide component and said oxidation metal oxide component are chemically bonded closely together so as to form a metal oxide complex having a crystalline structure,

the molar ratio of metal in the adsorption function metal oxide component to metal in the oxidation function metal oxide component being in a range of 1:3 to 1:6.